

NHDOT SPR2 PROGRAM

RESEARCH PROGRESS REPORT

INSTRUCTIONS:

Project Managers and/or research project investigators should complete a progress report at least every three months during the project duration. Reports are due the 5th of the month following the end of the quarter. Please provide a project update even if no work was done during this reporting period.

| | | |
|--|---|--|
| Project # 26962M | Report Period Year: 2018 <input checked="" type="checkbox"/> Q1 (Jan-Mar) <input type="checkbox"/> Q2 (Apr-Jun) <input type="checkbox"/> Q3 (Jul-Sep) <input type="checkbox"/> Q4 (Oct-Dec) | |
| Project Title: Evaluation of Gusset-less Truss Connection to Aid Bridge Inspection and Condition Assessment | | |
| Project Investigator: Erin S. Bell Co-Project Investigator: Ricardo Medina Phone: (603)862-3850 E-mail: erin.bell@unh.edu | | |
| Research Start Date: December 15, 2016 | Research End Date: December 31, 2018 | Project schedule status: <input type="checkbox"/> On schedule <input type="checkbox"/> Ahead of schedule <input checked="" type="checkbox"/> Behind schedule |

Brief Project Description:

The Memorial Bridge connecting Portsmouth, NH and Kittery, ME was re-opened to traffic in 2013. One of the major innovations of the reconstructed bridge is the first ever gusset-less truss connection in a vehicular bridge in the United States. Traditional gusset plates are the most vulnerable element in a truss-bridge structure and a source of significant cost, effort, and concern for bridge managers and owners. The goal of the proposed research is to integrate field-collected performance data, laboratory experimental testing, and physics-based structural modeling to develop a protocol to assess the condition and predict the remaining life of the gusset-less truss connections used at the Memorial Bridge. It is anticipated that the aforementioned approach will be modified to develop a framework to extend this protocol for application to future innovative structural elements.

The objectives of this project are to:

- Original Objective: Create two specimen pairs (A and B) of a scale model of a gusset-less connection from the Memorial Bridge. Specimen pair A (top chord connection) will be tested to failure in a quasi-static testing protocol and Specimen pair B (bottom chord connection) will be tested for fatigue performance. Modified Objective: Create two specimens that are a scaled model of the gusset-less connection from the Memorial Bridge focused on the bend radius weld section of the connection.
- Conduct quasi-static set of tests on each member of Specimen A to determine stress distribution in the connection.
- Evaluate these results in conjunction with field collected data and analytical models that are the work product of a complimentary FHWA-AID DEMO project to: (i) further understand and quantify the structural performance of the gusset-less connection, and (ii) validate analytical models.
- Conduct fatigue testing on Specimen pair B and collect performance data to determine the stress pattern and predict fatigue failure mode.
- Compare the findings of this project with the FHWA guideline for connection assessment to facilitate the development of an evaluation protocol for inspection and structural condition assessment.

Progress this Quarter (include meetings, installations, equipment purchases, significant progress, etc.):

Complete Literature Review and Finalize Testing Plan

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The literature review was completed by December 2017. Details of the testing plan are described in subsequent sections of this quarterly report.

Design and Construction of Scale Models

During the second quarter of 2017, weld specimens with and without defects were fabricated to evaluate the fatigue performance of intact and defective 7/16" welds. As part of this effort, a mock test was performed. Due to limitations of the testing machine, significant slippage was present during the cyclic test and an alternative testing approach was designed. The Civil and Environmental Engineering Department procured grips to be attached to the Instron Universal Testing Machine at the UNH Structural Engineering Laboratory (Figure 1). The advantage of using the aforementioned grips is twofold: (i) the grips prevents any slippage in the response once the specimens are exposed to cyclic loading, and (ii) time and resources are saved given that specimens do not need to be machined to a circular cross-section and specimens with square cross-sections can be tested without modifications. Figure 2 shows one of the specimens to be tested. The only machining necessary involved reducing the cross-section in the middle of the specimen (where the weld is located) in order to induce fatigue failure at this location. The grips arrived toward the end of the third quarter and testing in October and November demonstrated that they were defective. Material Testing Technology (MTT) were contacted, and after a few weeks going back and forth with them, the original grips were returned and a new set of grips were sent to us at the beginning of December. Thus, testing of the weld specimens is now schedule for the first quarter of 2018. Fortunately, this testing can be done in parallel with testing of the small-scale specimens of the gusset-less connection.



Figure 1: Original grips installed at the Instron Machine

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Figure 2: Example weld specimen

Due to the focus on the fatigue testing in the small-scale connection during this quarter, the testing on the weld specimen was not performed in the first quarter of 2018 and it is planned to happen in the beginning of the next quarter. The grips from Material Testing Technology (MTT) are still available for the test.

Analytical Models of Small-scale Physical Specimens

This task was completed in the first quarter of 2018.

Fatigue Testing

■ Setup

In the beginning of this quarter, the support components of the test setup were delivered. Figure 3 is a drawing of the setup. Moreover, a vertical support for the actuator was designed. The goal of this support is to hold part of the actuator's weight and, on top of the support there is a roller, which only carries vertical load, still allowing movement in the horizontal direction. This mentioned support also has neoprene in between the roller and the block to isolate any frictional effects. Figure 4 shows pictures of the reaction block and bracket.

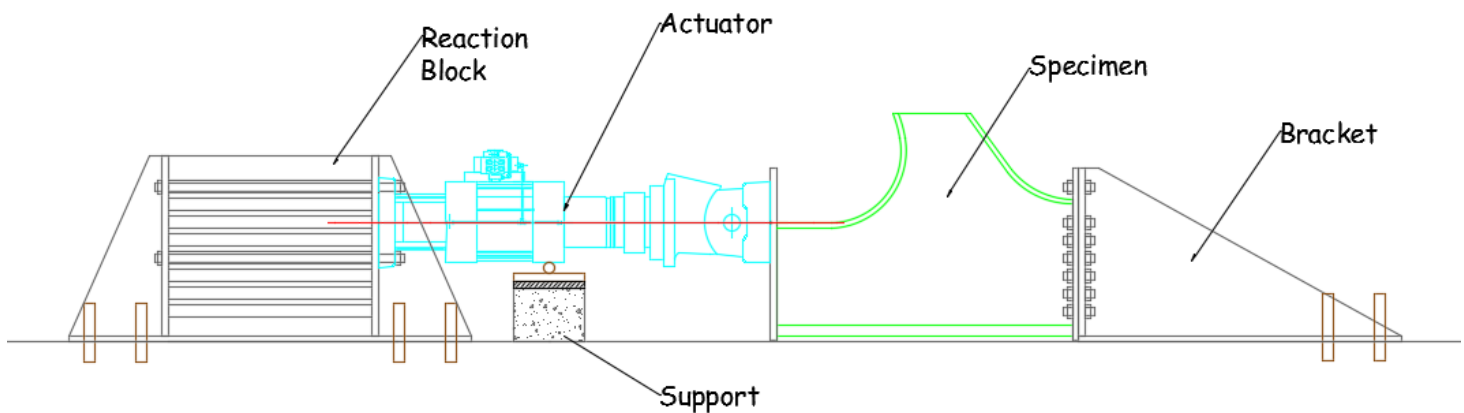


Figure 3: Schematic of setup for fatigue testing

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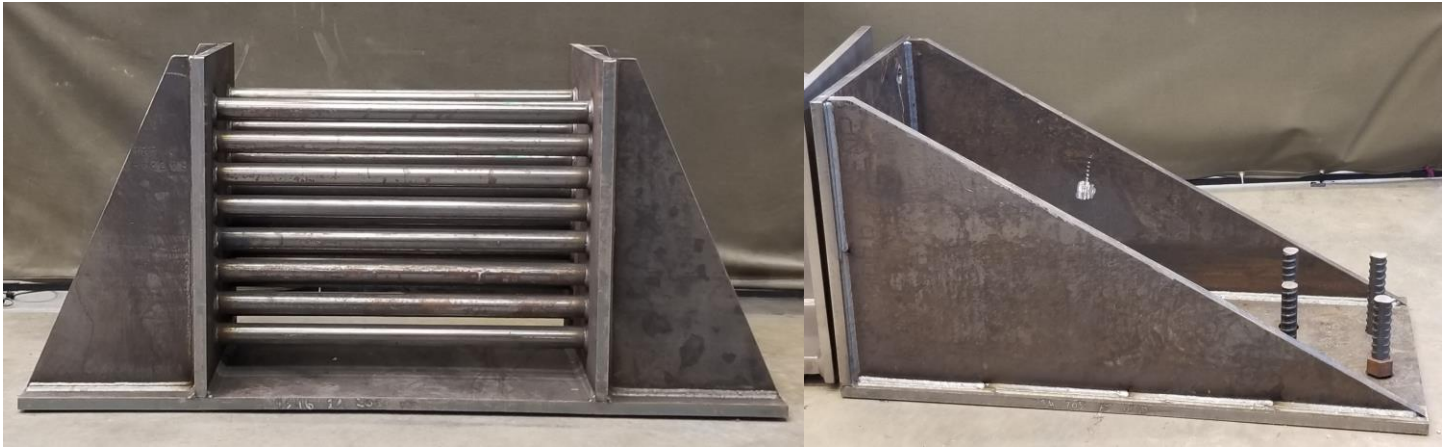


Figure 4: Reaction block and bracket

▪ Specimen

In February, the two specimens were delivered from CANAM Bridges. Figure 5 shows pictures of the first specimen to be tested. The specimens were sand blasted prior from shipping.

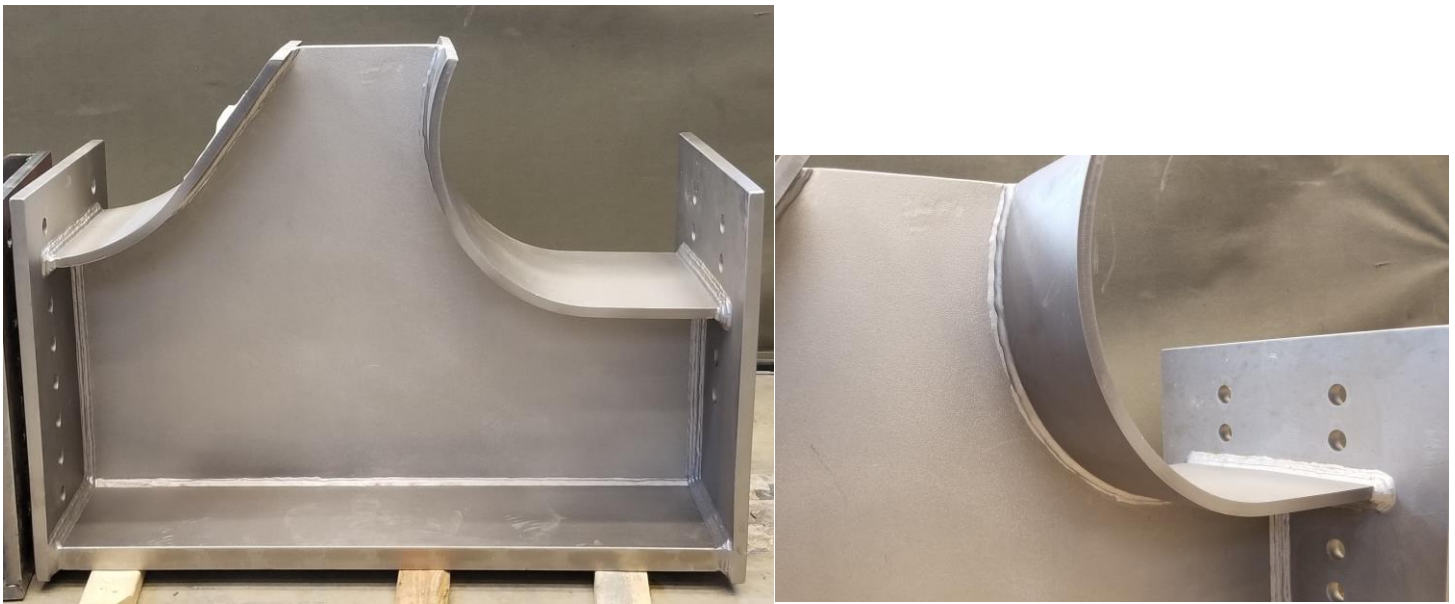


Figure 5: Specimen

▪ Instrumentation

During this quarter, the instrumentation plan was defined and the material ordered. The first decision was to use the same strain rosettes specifications that the Memorial Bridge is instrumented. From a rosette, strain is collected from all directions, allowing to calculate principal strains in the location where it is bonded and then apply equations to convert to principal stresses. It is important to have the principal stresses at the area under the curvature to compare with the maximum principal stresses due to fatigue provided by HNTB Corporation in their Summary Calculation. This strain rosette is spot welded to the surface, and the company that sells it, Hitec Products, provided instructions and training for the graduate student for the proper installation of the rosettes. In addition, uniaxial strain gages are installed at the specimen close to the supports to verify boundaries conditions. Figure 6 shows the locations of the strain rosettes and uniaxial gages in both sides of the specimen.

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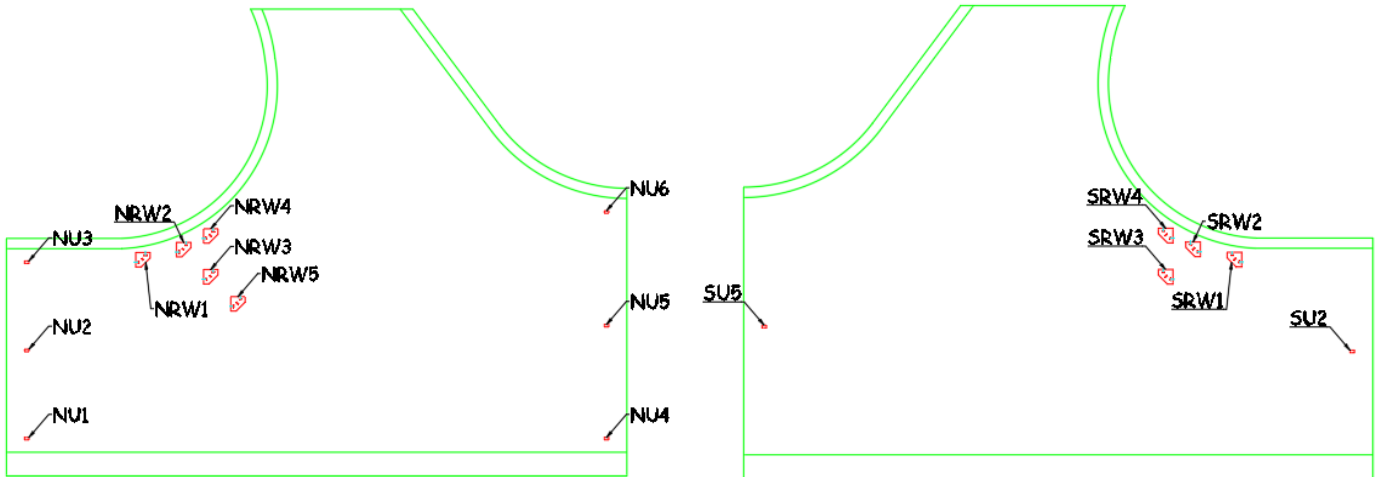


Figure 6: Gages instrumentation north (left) and south (right) side of the specimen

As part of the instrumentation, LVDTs will be placed at the plates located at each end of the specimen. The LVDTs are held by clamps which use a steel stand to adjust their height. Having the LVDTs at those specified locations will provide information of any rotation of the plates, which is important for the data analysis and model verification. In addition, the pipes of the reaction block are instrumented with uniaxial strain gages.

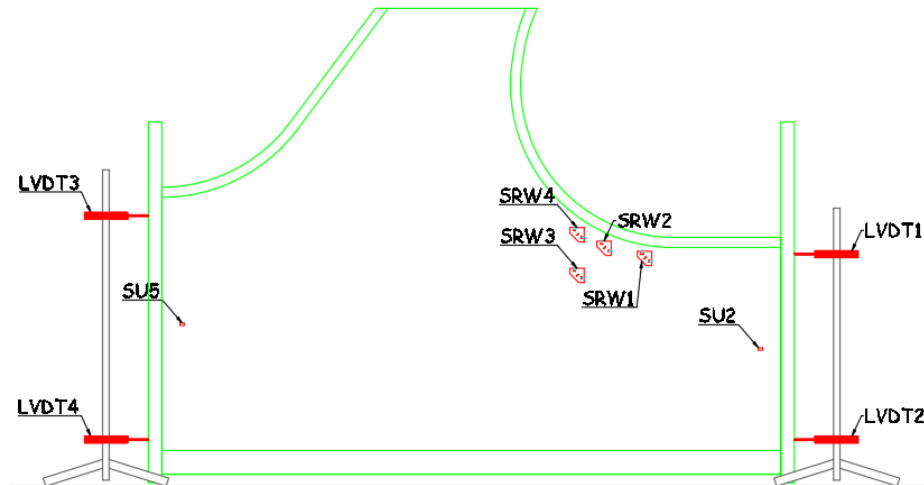


Figure 7: Illustration of LVDTs locations

For the gages installation, the surface was prepared accordingly with the recommendation, which consists in sanding the surface until a smooth and clean surface is achieved, and then cleaning with the appropriate chemicals.

■ DIC instrumentation

In addition to the strain gages shown in Figure 6, Digital Image Correlation (DIC) will be utilized as a non-contact measurement method. DIC is a measurement method that identifies groups of pixels, called subsets, and tracks the movement of those subsets across multiple images. The tracking is calculating the displacement vectors of the subsets and using them to calculate displacement and strain with relation to a reference image. This method can be used for both two- and three-dimensional measurements of the strains and displacements of the surface of the specimen. The advantage to DIC as a measurement tool is that it provides measurements across the entire surface that is captured by

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the cameras as opposed to strain gages, which are limited to discrete points on the specimen. Additionally, the surface preparation needed for DIC is not significant compared to strain gages.

In this test, both two- and three-dimensional DIC will be used for different reasons. The two-dimensional DIC will be used to capture strains and displacements in the web of the connection during an initial static-loading test. Figure 8 shows a picture of the instrumentation for the initial test. The goal of this initial test is to use DIC to identify the strain contours of the specimen given the applied load which should match with the strain contours provided by HNTB Corporation, as well as the strain contours from the finite element model (FEM) of the connection. These measurements will be compared to the strain gages in NUI1, NUI2 and NUI3 (Figure 8) to verify that the measurements are accurate. If the measurements match those of the gages, there will be confidence in the DIC measurements and the strain contours identified from this test. These contours will be used to finalize the locations at which the strain rosettes will be placed for the fatigue test.

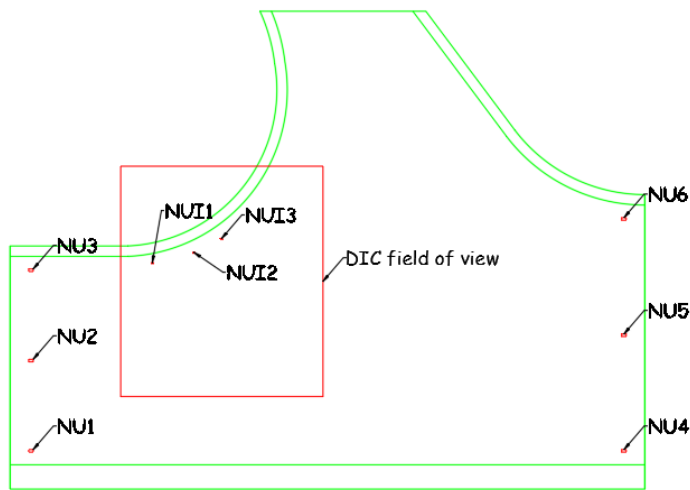


Figure 8: Instrumentation for initial test

The three-dimensional DIC will be used for the full-scale fatigue test to capture a unique area-of-interest. The area-of-interest will be focused on the interaction between the web and the underside of the top flange, depicted in Figure 9. Due to the geometric constraints, and not wanting to damage the weld with surface preparation, strain gages cannot be placed on or particularly close to the weld. Using three-dimensional DIC in this area will characterize the behavior, through displacement and strain measurements, of the web and flange as well as the weld.

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Figure 9: Web to flange DIC field of view

As a note, the areas shown as field of view are still not ready for testing. A speckle pattern will be done with a special speckle roll, which will create the contrast in the images captured by the cameras.

- Test specifications

As mentioned in previous reports, the fatigue test are consist in cyclic tests, initializing at the design load stress, followed by the allowable stress from the fatigue category of the weld and then extrapolated until failure happens and/or the capacity of the actuator is reached. The frequency of the test was decided in 3.5 Hz only in tension. Figure 10 is a fatigue load protocol example for 3 seconds of test. The 12 kips load shown in the figure is the load necessary to achieved the expected design stresses in the weld under the curvature.

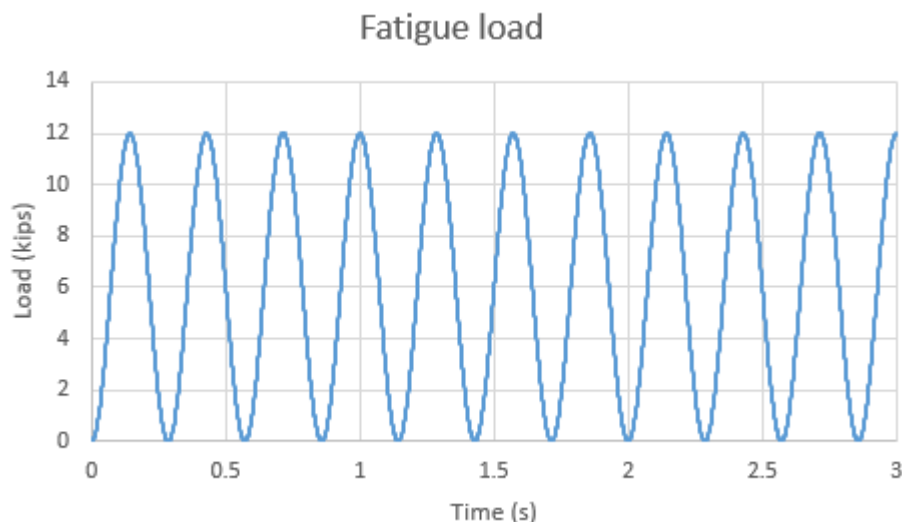


Figure 10: Fatigue load protocol example

Unfortunately, the test was not realized in the first quarter due to a delay in the calibration of the actuator. Initially, the calibration of the actuator would be done at UNH as soon as the reaction block is available. When MTS (actuator's brand) did their visit prior to the installation, it was identified that the actuator needed to return to the company for calibration.

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The actuator returned from calibration in April 4th, and the visit for installation is schedule for April 9th. The test of the first specimen will be performed in the month of April.

- **Coupon Test**

For material characterization, coupon specimens are being fabricated and will be tested under tensile load at the Instron Machine. The plates for the tensile test were provided by CANAM Bridges, and the specimens are under fabrication at the UNH Machine Shop.

- **Residual stress**

In wanting to characterize the stresses that the connection is under, it has been decided to perform residual stress tests. The residual stress test that will be performed is a blind-hole analysis. This means that the specimen will be fitted with a specialized strain rosette and a small-diameter hole will be incrementally drilled into the specimen to a specified depth. This drilling will relieve the stresses around the hole, which will be measured by the strain rosette. These strains can be mathematically related to the residual stresses that were present in the specimen. Due to the unique fabrication of this specimen, it is planned to identify the residual stresses due to the cold-bending process, and the residual stresses around the weld area. As a comparison, the test will also be performed on a plate of the same material that has not undergone any fabrication.

Data Analysis and Interpretation of Laboratory Testing

There was no progress on this task during this reporting period.

Evaluation Protocol for Inspection and Condition Assessment

There was no progress on this task during this reporting period.

Final Report and Presentation

There was no progress on this task during this reporting period.

Meetings

During this quarter, two relevant meetings took place. A TAG meeting was held at the NHDOT offices in Concord on October 31, 2017 to update the NHDOT on the research activities and solicit their input on the remaining research tasks. Dr. Bell (PI), Dr. Medina (co-PI), and Fernanda Fischer (graduate student) participated in this meeting from UNH. Moreover, Dr. Bell, Fernanda Fischer and Maryam Mashayekhizadeh (graduate student) traveled to New York City and met with Ted Zoli at the HNTB offices to discuss various aspects of this project, especially some of the details related to future fatigue testing activities that could be part of future projects depending on the results of this research effort.

Items needed from NHDOT (i.e., Concurrence, Sub-contract, Assignments, Samples, Testing, etc):

There are no items needed from the NHDOT at this time.

The research team would like to request a TAG meeting for April at UNH once the test set up is installed and the testing is underway. This meeting could be live or virtual using Zoom® to allow NHDOT interested personnel to see the test.

Anticipated research next 3 months:

Complete the fatigue testing of weld samples with the new grips on the universal testing machine at the structural high bay.

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Conduct strength testing of the small-scale physical specimens of the gusset-less Memorial Bridge connection to verify the structural models.

Begin fatigue testing of the small-scale physical specimens of the gusset-less Memorial Bridge connection.

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Circumstances affecting project: Describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope, and budget, along with recommended solutions to those problems.

As described in the previous quarterly reports, delays associated with specimen fabrication, the need to modify the Instron Universal Testing Machine at UNH, the receipt of defective grips for fatigue testing of weld specimens, technical issues relating to the data acquisition system at the Memorial Bridge have negatively affected the schedule of this project.

| Tasks (from Work Plan) | Planned % Complete | Actual % Complete |
|---|--------------------|-------------------|
| Evaluation of Gusset-less Truss Connection to Aid Bridge Inspection and Condition Assessment | | |
| Literature Review and Finalize Testing Plan | 100 | 100 |
| Design and Construction of Small-scale Models | 100 | 100 |
| Quasi-Static Testing to Failure – Replaced by Load Test of the in-service connection at the Memorial Bridge | 100 | 100 |
| Validation of Structural Connection Analytical Model | 100 | 100 |
| Fatigue Testing | 75 | 20 |
| Data Analysis and Interpretation of Laboratory Testing | 0 | 0 |
| Evaluation Protocol for Inspection and Condition Assessment | 0 | 0 |
| Final Report and Poster | 0 | 0 |
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